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COMPLIANT POLISHING ELEMENT AND METHOD OF MANUFACTURING THE SAME

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COMPLIANT POLISHING ELEMENT AND METHOD OF MANUFACTURING THE SAME

FIELD OF THE INVENTION

The invention relates generally to the field of precision surface polishing, and in particular to polishing of general surfaces. More specifically, the invention relates to a tool for polishing precision surfaces.

BACKGROUND OF THE INVENTION

It is well known in the art that precision surface polishing is often performed by large pads that execute planar or spherical motions relative to the surface to be polished. These large pads are either flat or spherical, depending on the shape of the surface to be polished. Because the pad shape and motion both match the surface, a large pad can contact the surface over a large area, and repetitive polishing motions can produce a precise surface by averaging effects.

However, for polishing general surfaces, such as aspheric optical surfaces, existing polishing devices and systems have proven woefully inadequate. For these surfaces, the contact between the polishing tool and the surface must be much smaller than the pads used for planar or spherical surfaces, because the local radius of curvature varies across the surface. Further, polishing pads that are entirely sufficient for polishing planar or spherical surfaces are not sufficiently compliant to accommodate the variations in curvature radius inherent in aspheric surfaces to be polished.

While there have been numerous attempts in the prior art to address the challenges presented when polishing aspheric surfaces, there has been limited success in overcoming the aforementioned problems. As an example, in one known device for polishing an aspheric surface, a small contact patch is used to contact the surface. In another instance, a large wheel device is used that achieves a small contact patch by exploiting magneto-rheological fluids. Further, other polishing systems that have attempted to solve the aforementioned problem have used a convex pad to polish the surface, sometimes with a pressing motion. One shortcoming with all of the above-mentioned polishing systems is that the

polishing tool is large relative to the contact patch, which makes it impossible to use for surfaces with small, deep concavities. There is one prior art attempt that seeks to overcome this latter problem disclosed in co-pending U.S. Patent Application Serial Number 10/318,787, filed December 13, 2002 by Stephen C. Meissner, titled "Sub-Aperture Compliant Toroidal Polishing Element," hereby incorporated herein by reference. The compliant polishing tool in U.S. Serial Number 10/318,787 uses a very small toroidal compliant tool to achieve a small polishing contact patch that can reach into small concavities.

One problem that is known to occur with the above and all of the existing compliant polishing tools is that a deficiency in polishing fluid coverage on the surface to be polished results as contact pressure is increased between the polishing member and the surface. It is our experience that this deficiency arises because polishing fluid is forced away from the center of the contact region of the polishing member and surface to be polished, leaving a region deficient in fluid coverage for effective polishing. As a result, it is well known that prior art polishing devices limit the contact pressures that may be applied by the polishing member on the surface to be polished, which in turn limits material removal rates. Consequently these compliant tools cannot achieve the polishing productivity and efficiency that might be attained if positive fluid flow throughout the contact was assured.

Therefore, there remains a need for a compliant polishing element for polishing surfaces, particularly aspheric surfaces, that provides a small contact patch that can reach into deep concavities, while maintaining fluid flow throughout the contact even while significant contact pressure is applied by the polishing member.

SUMMARY OF THE INVENTION

The present invention is directed to overcoming one or more of the problems set forth above. Briefly summarized, according to one aspect of the present invention, a precision polishing element has a substantially rigid support member having an outer perimeter for cooperating with a tool. The outer perimeter terminates at one end in a mounting surface to which is mounted a

polishing member. Important to the invention, polishing member has a plurality of regularly spaced compliant polishing portions or lobes for engaging a surface to be polished. Each one of the regularly spaced compliant polishing portions project outwardly from a recess separating nearest adjacent compliant polishing portions. The recess separating nearest adjacent compliant polishing portions provides a polishing fluid transport region there between when the polishing member is in compressive contact with the surface to be polished.

The present invention has numerous advantages over prior art developments. For instance, the polishing device can polish general surfaces, such as aspheric optical surfaces. Moreover, the polishing device of the invention eliminates deficient polishing fluid zones on the surface to be polished. Further, the polishing device of the invention is simple to construct and easy to utilize.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features, and advantages of the present invention will become more apparent when taken in conjunction with the following description and drawings wherein identical reference numerals have been used, where possible, to designate identical features that are common to the figures, and wherein:

Figure 1A is an elevated, slightly tilted side view of the polishing device of the invention;

Figure 1B is an elevated side view of the polishing device of Figure 1A partially sectioned and exploded to show the lobes of the polishing member;

Figure 2 is a schematic of the polishing tool of the invention during polishing;

Figure 3A is an elevated side view of an alternative embodiment of the invention;

Figure 3B is an elevated side view of the embodiment of Figure 3A partially sectioned and exploded to show the features of the polishing member;

Figure 4 is an enlarged perspective view of the compliant polishing member used in the embodiment of Figs. 3A and 3B;

Figures 5A-5F are top plan views of several exemplary compliant polishing members used in the invention;

Figure 6A is an elevated side view of another alternative embodiment of the invention;

Figures 6B is an elevated side view of the embodiment of Figure 6A partially sectioned and exploded to show the polishing member;

Figure 7 is an enlarged perspective view of the compliant pad illustrated in Figs. 6A and 6B;

Figures 8A is an elevated side view of yet another embodiment of the invention;

Figure 8B is the embodiment of Figure 8A partially sectioned and exploded to show the polishing member;

Figure 9 is an enlarged perspective view of the compliant pad of the embodiment illustrated in Figs. 8 A and 8B;

Figure 10 is a perspective view of a polishing tool containing the polishing element of the invention; and,

Figure 11 is an elevated side view of the polishing tool of Figure 9 in service polishing a surface;

DETAILED DESCRIPTION OF THE INVENTION

Turning now to the drawings, and more particularly to FIGS. 1A and 1B, polishing element 10 of the first embodiment of the invention is illustrated. According to FIGS. 1A and 1B, polishing element 10 has a substantially rigid support member 12 with an outer perimeter 14 for cooperatively associating with a tool, such as the exemplary rotary tool shown in FIG. 10. The outer perimeter 14 terminates at one end with a mounting surface 16 provided for affixing a compliant polishing member or pad 18. Compliant polishing member 18 may be affixed to mounting surface 16 in any number of ways including gluing, friction or interference fit, or with a screw. Moreover, the compliant polishing member 18 may be molded to the mounting surface 16.

Referring to FIGS 1A, 1B, and 2, polishing tool 26 comprises a polishing fluid applicator or nozzle 23 and the polishing element 10 (compliant

polishing member 18 only illustrated) in a precision surface polishing application, for example, polishing an aspheric optical surface 22. Compliant polishing member 18 of the invention has a plurality of regularly spaced polishing portions or lobes 20 for spreading polishing fluid 21 across the surface 22 to be polished. The recess 24 between nearest adjacent lobes 20 enables a predetermined amount of polishing fluid 21 to be spread in a predictable manner across the surface 22 to be polished. During a precision polishing application, the polishing element 10 is structurally mounted into a spindle (not shown) of a rotary device (FIG. 11) via the substantially rigid support member 12 (FIGS. 1A and 1B). The polishing element 10 is rotated while in compressive contact with the surface 22 to be polished. A polishing fluid, such as a slurry of abrasive particles, is disposed, typically via nozzle 23, in an interfacial area between adjacent lobes 20 of the compliant polishing element 10 and the surface 22 to be polished. As the polishing element 10 is rotated by the rotary device, the plurality of spaced polishing portions or lobes 20 traps polishing fluid 21 between the surface 22 to be polished and the nearest of the lobes 20. This action forces the polishing fluid 21 across the surface 22 to be polished. In the process, it also prevents polishing fluid starvation from any area on the surface 22 to be polished.

Referring to FIGS. 3A, 3B, and 4, in a second embodiment of the invention, polishing element 30 has a substantially rigid support member 33 and a compliant polishing member 35 mounted on an end portion (not shown) of the support member 33. Compliant polishing member 35 has a plurality of spaced lobes 37 each being connected to a nearest adjacent lobe 37 by a recess 39. A continuous groove 41 passes through each of the lobes 37 about the circumference of the compliant polishing member 35. A portion of each lobe 37 separated by the groove 41 is directed inwardly towards the groove 41. Groove 41 prevents polishing fluid 21 from escaping from between the lobes 37 and surface to be polished 22 (shown in Fig. 2) as polishing element 30 rotates. According to FIG. 4, continuous groove 41 is clearly shown in a close-up view of the polishing element 30.

Referring now to FIGS. 5A-5F, illustrated are several substantially star-shaped configurations 40, 50, 60, 70, 80, 90 for compliant polishing member 18 or pads. Each of these substantially star-shaped configurations 40, 50, 60, 70, 80, 90 may be used in the polishing element 10 of the invention to produce substantially the same result. More particularly, each of the substantially star-shaped configurations 40, 50, 60, 70, 80, 90 produces similar favorable fluid dynamics at the interface of the surface 22 and compliant polishing member 18. According to FIG. 5A, configuration 40 has typically six lobes 42 having rounded peaks 44 separated by slightly arcuate recesses 46 which form a slightly arcuate angled lobe 42. According to FIG. 5B, configuration 50 has a plurality of lobes 52 (typically six) each having a relatively flat and substantially straight peak 54 separated from the nearest adjacent lobe 52 by a slightly curved recess 56 to form a flat, substantially straight lobe 52. According to FIG. 5C, configuration 60 has a plurality of lobes 62 (typically six) each having a relatively narrow and slightly rounded peak 64 separated by a slightly curved recess 66 to form a substantially straight lobe 62. According to FIG. 5D, configuration 70 has a plurality of lobes 72 (typically six) each having a relatively narrow and round peak 74 separated from the nearest adjacent lobe 72 by substantially curved recess 76 to form a narrow, substantially arcuate shaped lobe 72. According to FIG. 5E, configuration 80 has a plurality of lobes 82 each having a narrow rounded peak 84 separated from the nearest adjacent peak 84 by substantially wide, arcuate shaped recess 86 to form a substantially wide arcuate lobe 82. Finally, according to FIG. 5F, configuration 90 has a plurality of lobes 92 each having a narrow, very round peak 94 separated from the nearest adjacent narrow, very round peak 94 by a very arcuate shaped recess 96 to form a narrow, very arcuate lobe 92.

Turning now to FIGS. 6A, 6B, and 7, a third embodiment of the compliant polishing element 100 is illustrated. According of FIGS. 6A, 6B, and 7, compliant polishing element 100 has a substantially disk-shaped polishing member 102 supported on substantially rigid support 104. A central opening 106 passes through the compliant polishing member 102 for locating onto the substantially rigid support 104. As indicated above, substantially rigid support

104 cooperates with a rotary tool for polishing a work piece (Shown in FIG. 10). In this embodiment, compliant polishing element 100 is characterized by a plurality of spaced depressions 108 arranged in the circumference 110 of the compliant polishing member 102. the portions of the circumference 110 between the depressions 108 form the compliant polishing portions 112. As in the previous embodiments, the spaced depressions 108 trap the polishing fluid between the surface 22 to be polished and the compliant polishing member 102 during polishing. Further, spaced depressions 108 assure that the polishing fluid will spread across the surface without leaving voids. Depressions 108 may be formed in the circumference of compliant polishing member 102 in a number of ways, including cutting or forming during a molding process.

Referring now to FIGS. 8A, 8B, and 9, a fourth embodiment of the compliant polishing element 120 is illustrated. In this embodiment, the compliant polishing element 120 has a substantially rigid support 122 and a compliant polishing member 124 attached to one end of the rigid support 122. Important to the invention, compliant polishing member 124 has a plurality of spaced compliant polishing portions 126 each having a surface shape generally in the form of a torus, as best seen in FIG. 9. The compliant polishing portions surround recessed portions 128. As in previous embodiments, the substantially torus-shaped compliant polishing member 124 traps polishing fluid between the interface of the surface 22 to be polished and the recessed portions 128 of the compliant polishing member 124. Compliant polishing member 124 further provides means for distributing the polishing fluid across the surface area of the surface 22 to be polished.

Referring now to FIGS. 10 and 11, tool 200 for precision polishing a general surface, such as an aspheric optical surface, is shown. In FIG. 11, a partial schematic of polishing element 220 of polishing tool 200 is shown polishing an aspheric surface 240 (FIG. 11). According to FIG. 10, polishing tool 200 comprises a movable work piece holder 210 for precise engagement by compliant polishing member 230 of polishing element 220. Polishing element 220 comprises compliant polishing member 230 affixed to substantially rigid

support member 250. In the preferred embodiment, polishing element 220 is slightly angled from the polishing surface normal (FIG. 11). The polishing fluid is not shown. This configuration allows polishing of flat surfaces and concavities using a uniform contact condition.

The invention has been described with reference to a preferred embodiment. However, it will be appreciated that variations and modifications can be effected by a person of ordinary skill in the art without departing from the scope of the invention.

PARTS LIST:

10	first embodiment of polishing element
12	substantially rigid support member
14	outer perimeter of support member 12
16	mounting surface
18	compliant polishing member of first embodiment
20	lobes
21	polishing fluid
22	surface to be polished
23	nozzle
24	recess between nearest adjacent lobes 20
26	partial polishing tool
30	second embodiment of polishing element
33	substantially rigid support member of second embodiment
35	compliant polishing member of second embodiment
37	lobes of second embodiment
39	recess separating nearest adjacent lobes 37
40	first configuration of compliant polishing member 18
41	continuous groove
42	lobes of first configuration
44	rounded peaks of lobes 42
46	slightly arcuate recess
50	second configuration of compliant polishing member 18
52	lobes of second configuration
54	substantially straight peak of lobe 52
56	slightly curved recesses between nearest adjacent lobes 52
60	third configuration of compliant polishing member 18
62	lobes of third configuration

Parts List – continued

64 slightly rounded peak of lobes 62

66 slightly curved recess between nearest adjacent lobes 62

70 fourth configuration of compliant polishing member 18

72 lobes of fourth configuration

74 round peak of lobes 72

76 substantially curved recesses between nearest adjacent lobes 72

80 fifth configuration of compliant polishing member 18

82 lobes of fifth configurations

84 narrow rounded peaks of lobes 82

86 substantially wide, arcuate shaped recess between nearest adjacent lobes 82

90 sixth configuration of compliant polishing member 18

92 lobes of sixth configuration

94 very round peaks of lobes 92

96 very arcuate shaped recess between nearest adjacent lobes 92

100 third embodiment of compliant polishing element

102 disk shaped polishing member of third embodiment

104 rigid support of third embodiment

106 central opening passing through member 102

108 spaced depressions in compliant polishing member 102

110 circumference of compliant polishing member 102

112 compliant polishing portions of polishing member 102

120 fourth embodiment of compliant polishing element

122 rigid support of compliant polishing element 120

124 compliant polishing member of fourth embodiment

126 spaced polishing portions

128 recessed portion

200 tool for precision polishing

210 movable work piece holder

220 polishing element of tool 200

230 compliant polishing member of element 220

Parts List – continued

240 aspheric surface

250 substantially rigid support member of element 220